



HumanIC project has received funding from the European Union's Horizon Europe research and innovation program under the Marie Skłodowska-Curie (HORIZON-MSCA-2022-DN-01, project no 101119726)



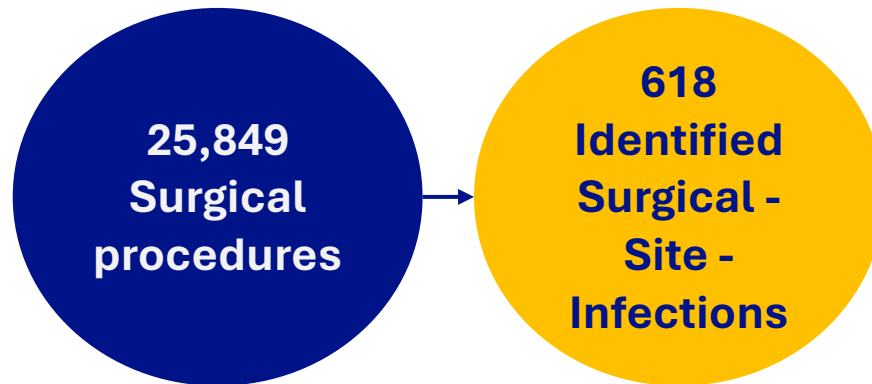
Low-order modelling and sensing for airflow in operating rooms

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Supervisors: Stefano Discetti,
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PhD Aerospace Engineering UC3M
Doctoral Meetings 2026
2nd and 3rd June 2026

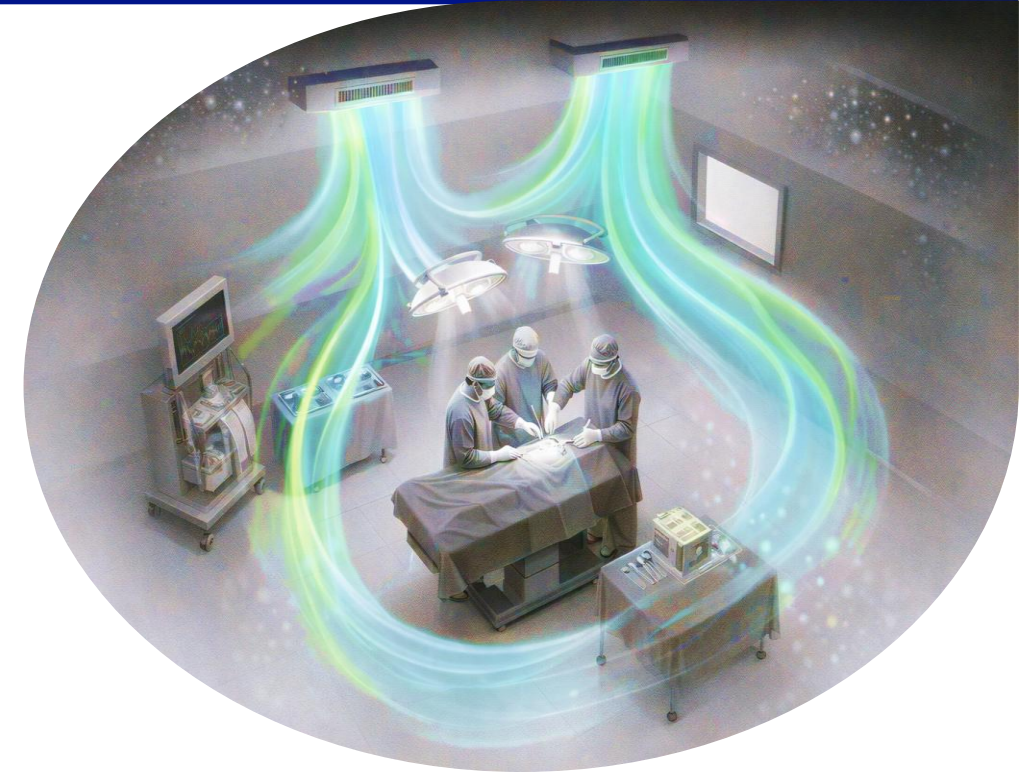
- Background & Motivations
- Research Gap
- Experimental methodology
- Preliminary PIV Results
- CFD Validation
- Conclusion & Future steps
- Achievements

- Operating room (OR) can be a hazardous environment, particularly for patients.



Surgical-Site-Infection Rate:
2.76 per 100 surgical procedures

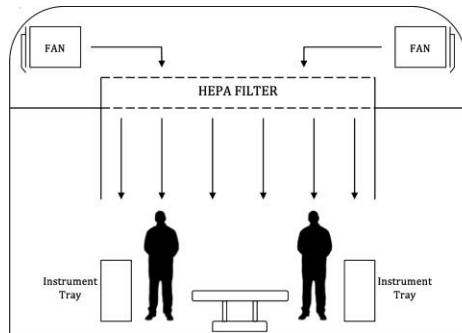
[1]



- Operating room (OR) can be a hazardous environment, particularly for patients.
- The airflow system acts as a preventive control measure.
- The reported results are still controversial and sometimes contradictory:
it is time to look at the problem from a fluid-dynamics perspective.



Unidirectional Airflow system



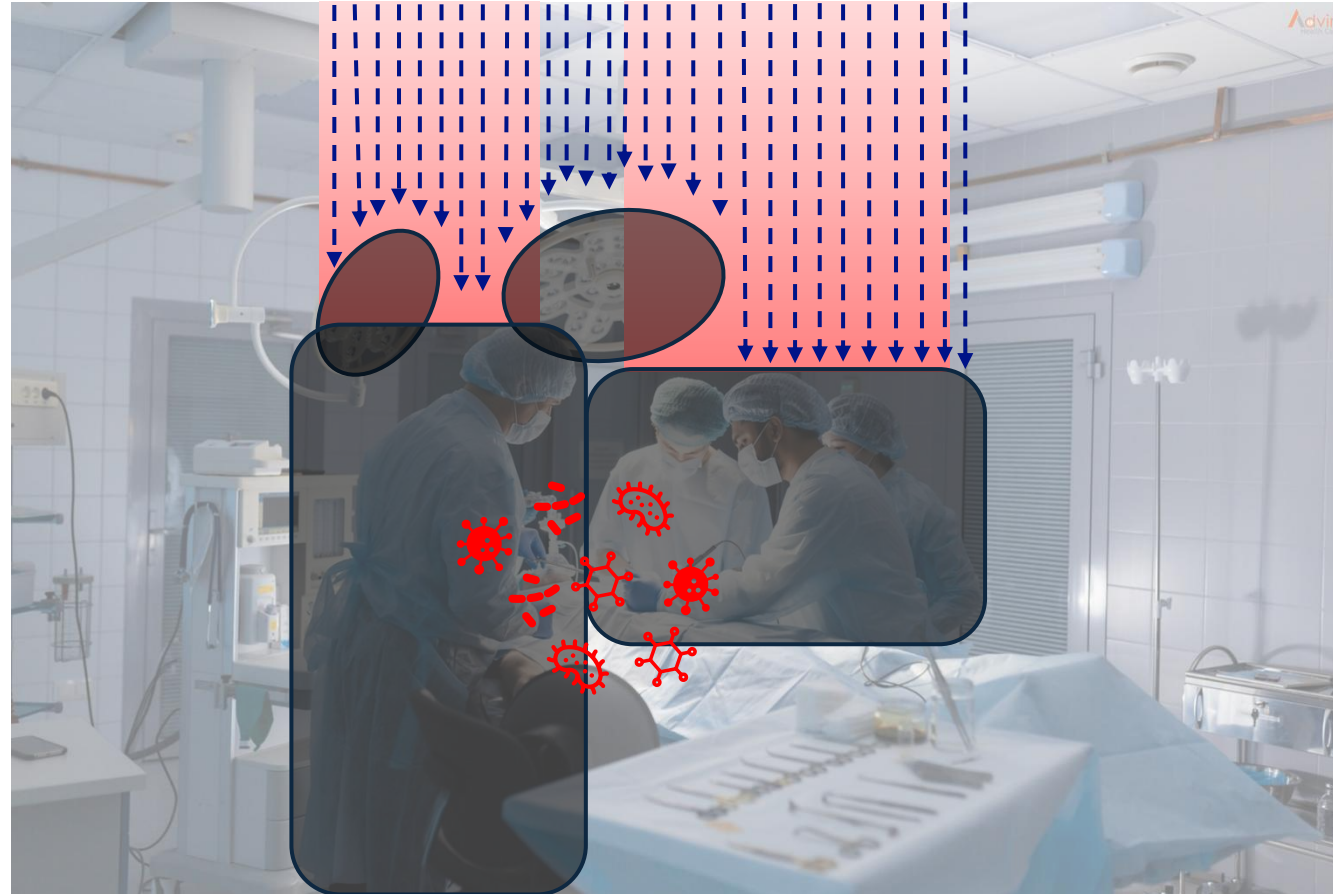
[2]



Advin Health Care

Main influencing factors:

- Buoyancy-driven thermal plumes from staff and patients
- Obstructions caused by lights, equipment, and personnel



Advin Health Care

Main objectives:

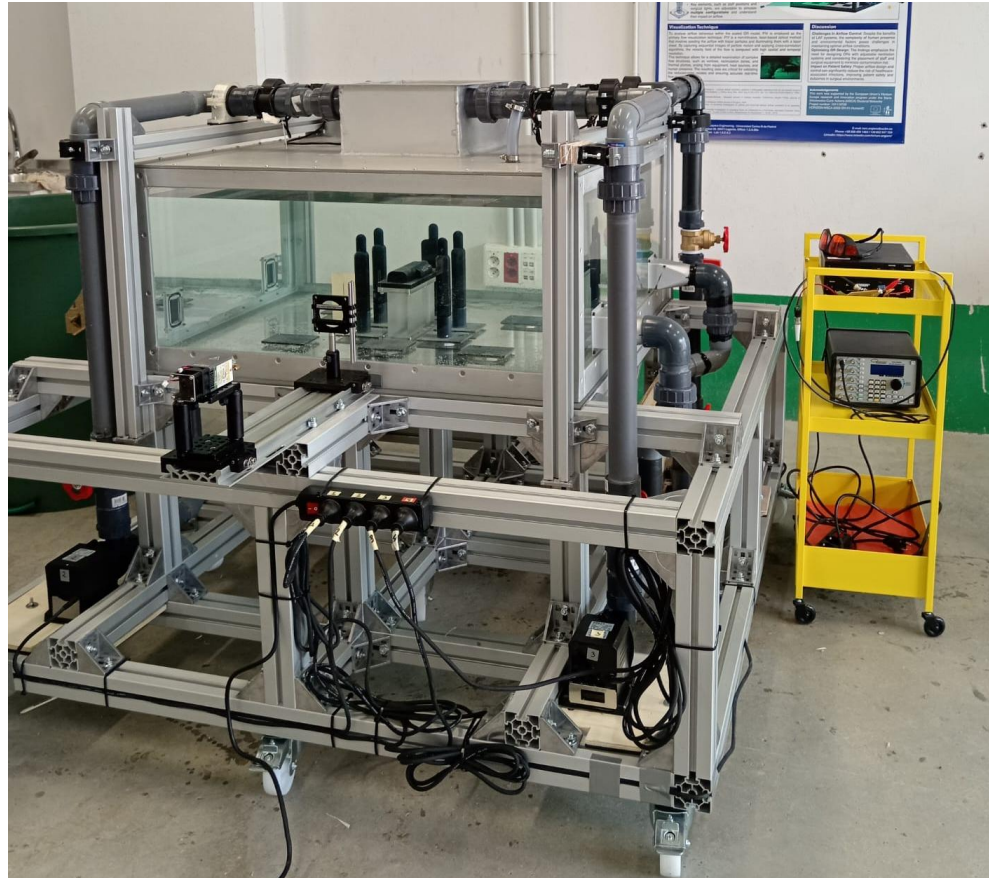
- Reconstruct the airflow pattern in operating rooms (ORs) in near “real time”
- Using a limited number of sensors

Approaches:

- Develop reduced-order models (ROMs) based on sparse sensing
- Train and validate these models using an experimental database obtained from PIV measurements in a scaled operating room.

Scaled model of an Operating Room with buoyancy-driven thermal plume

Study	Fluid	Model Scale	Thermal Similarity	OR?
Sattari (2013) [3]; Fallenius (2013) [4]	Water	0.30 x 0.2 x 0.01 m	Isothermal No obstructions	No
Zhang (1993) [5]	Air	1 : 4	Non-Isothermal	No
Mesenhöller et al. (2022) [6]	Water	1.00 × 0.67 × 0.46 m; 1 : 6.25	Isothermal No obstructions	No
Mukhaiber and Turner (2023) [7]	Water & Air	1 : 10	Isothermal & Non-Isothermal	Yes
Stevenson /ASHRAE (2013) [8]	Air	n.r.	Non-Isothermal	Yes
de Santiago Casado (2015) [9]	Air	0.87 × 0.87 × 0.50 m; scale 1 : 7	Non-Isothermal	Yes



- Water-based model
Partial dynamic similarity
 $Re = 13,953$; $Ri = 2.27$
- Dimensions: $87.5 \times 87.5 \times 37.5$ cm (1:8)
- Thermal Plume: Heated manikins
- Obstructions: surgical lamps, anesthesia machine

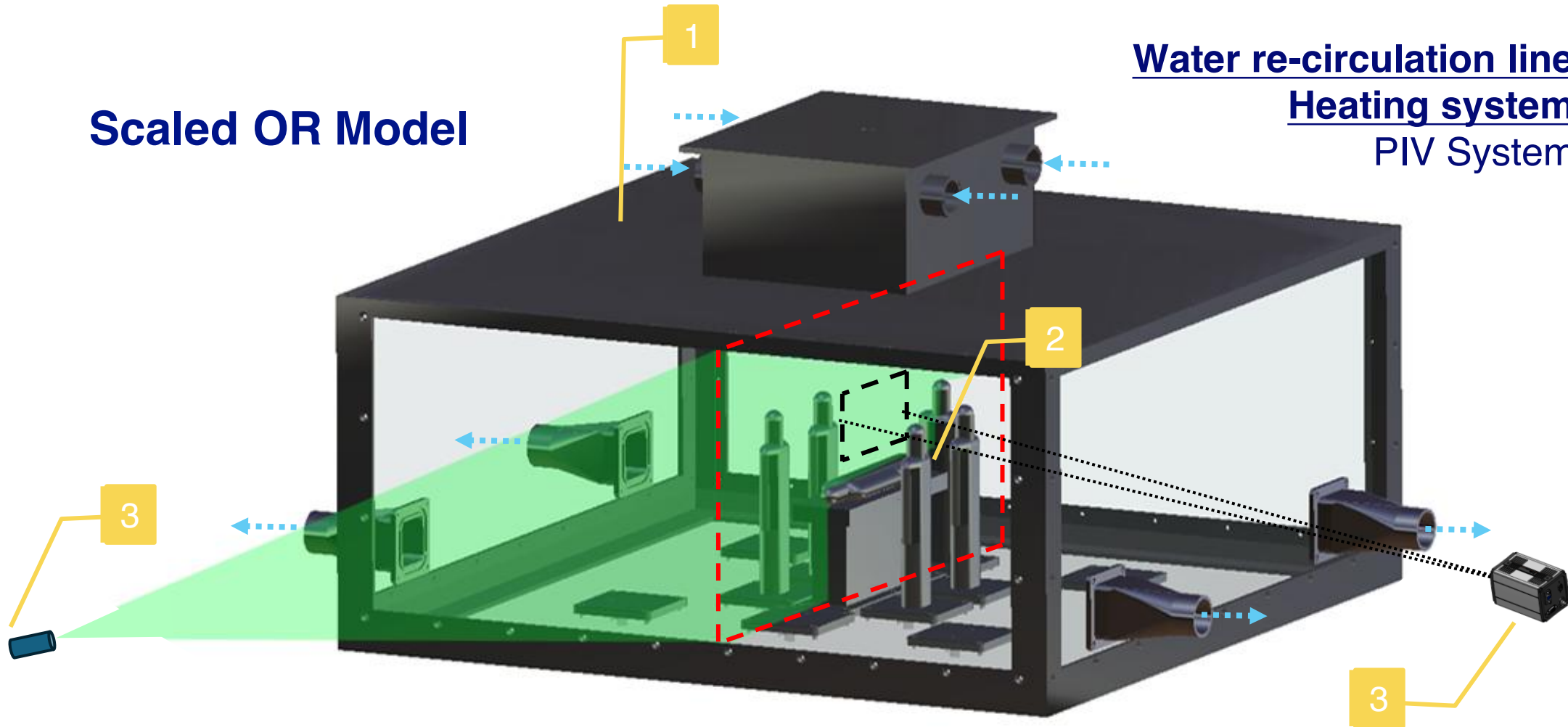
Measurement:

Particle Image Velocimetry (PIV) of velocity field:

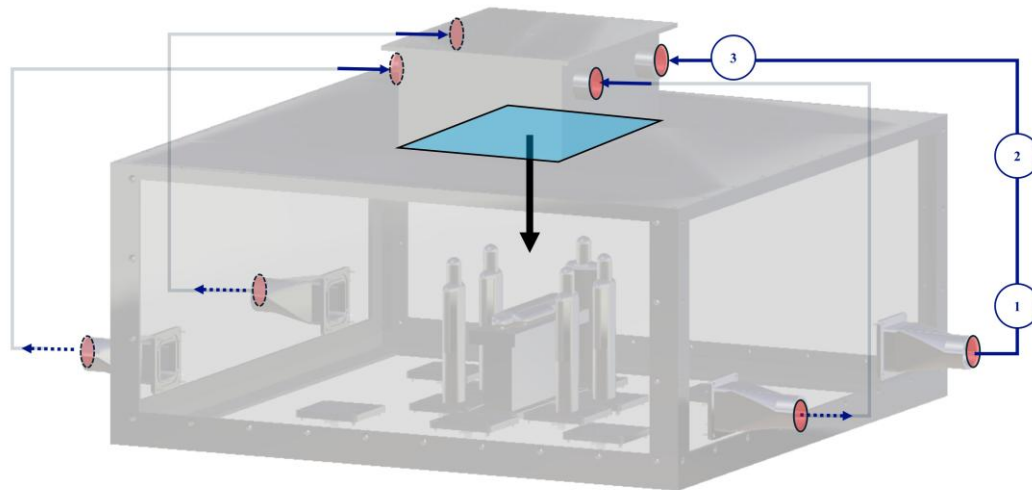
- Surgical zone
- Full field via stitching technique

Scaled OR Model

Water re-circulation line .1
Heating system .2
PIV System .3

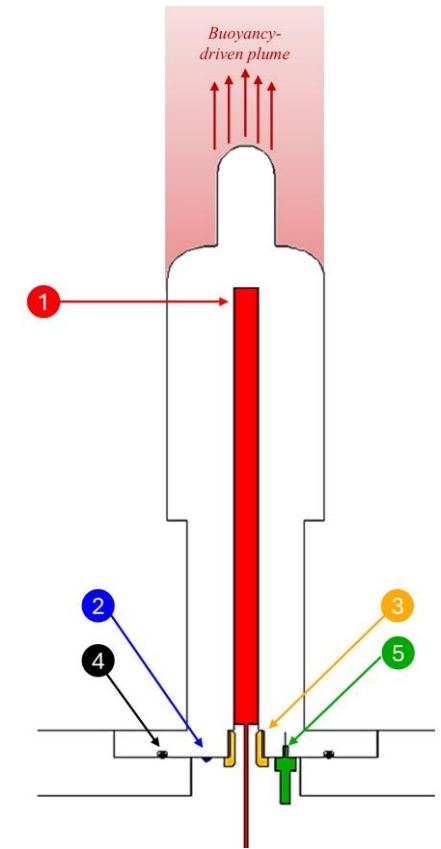


Water re-circulation system

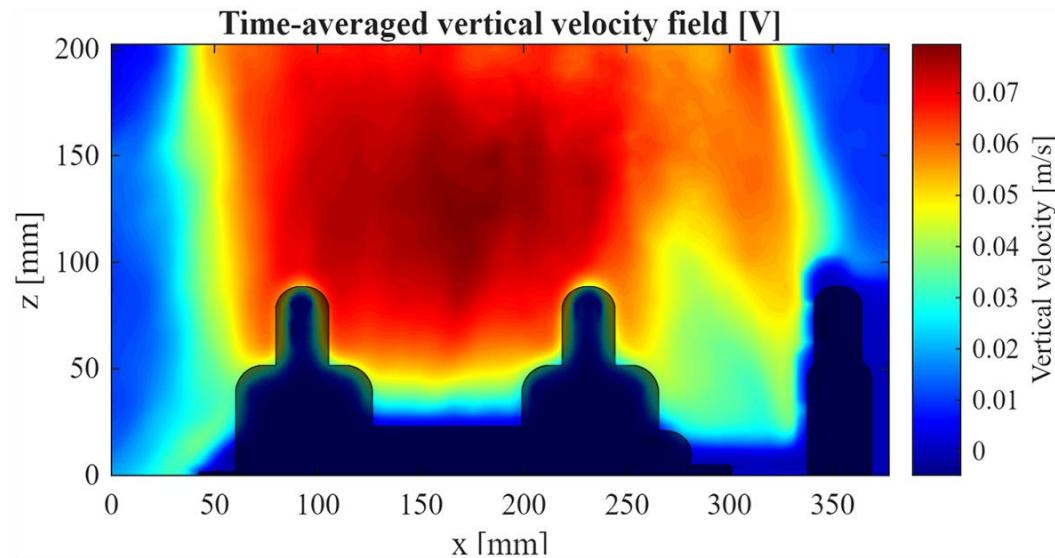


- (1) Water Pump 14000 l/min
- (2) Valve
- (3) Water Flow Meter (flow rate sensor)

Manikins heating control system

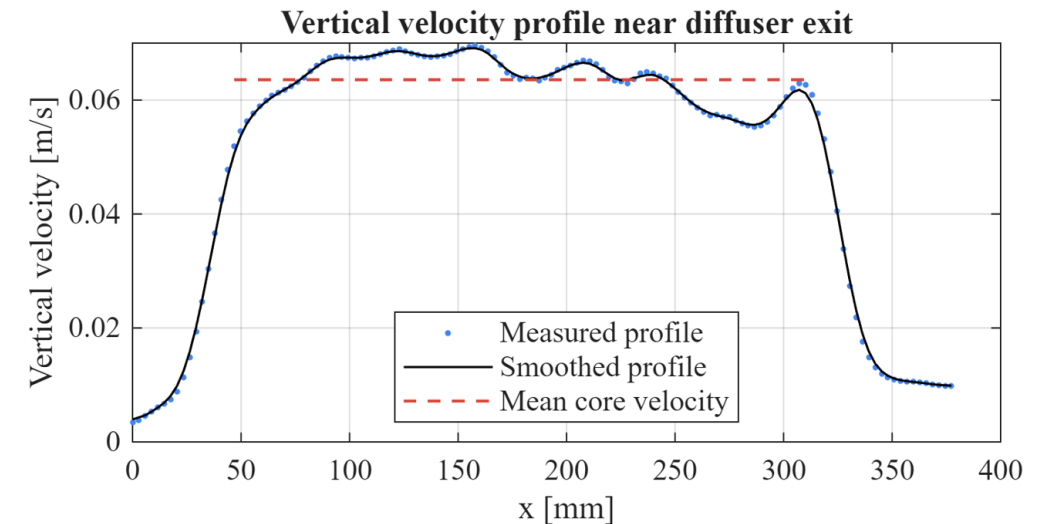


- (1) Cartridge Heater (800W)
- (2) Ground Wire
- (3) Stopper Nut
- (4) O-Ring
- (5) Screwed Thermocouple



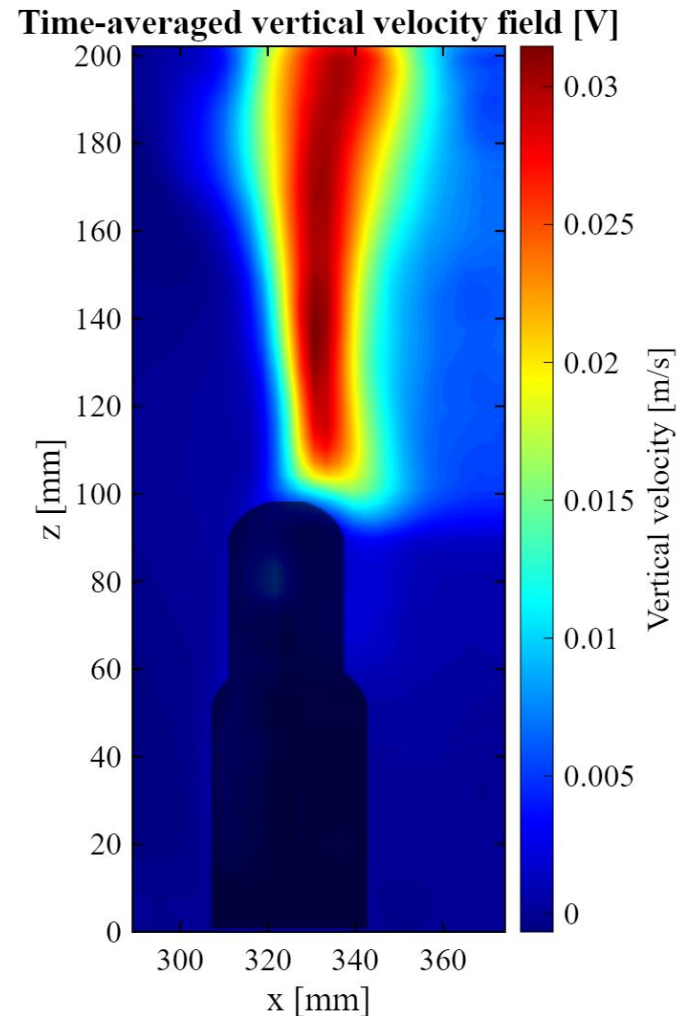
Time-averaged vertical velocity field under isothermal conditions.

A dominant downward core flow is observed beneath the ceiling diffuser, with lateral gradients near the edges and local disturbances induced by geometric obstructions.



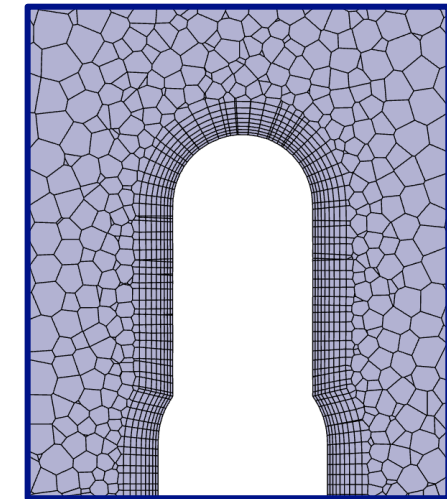
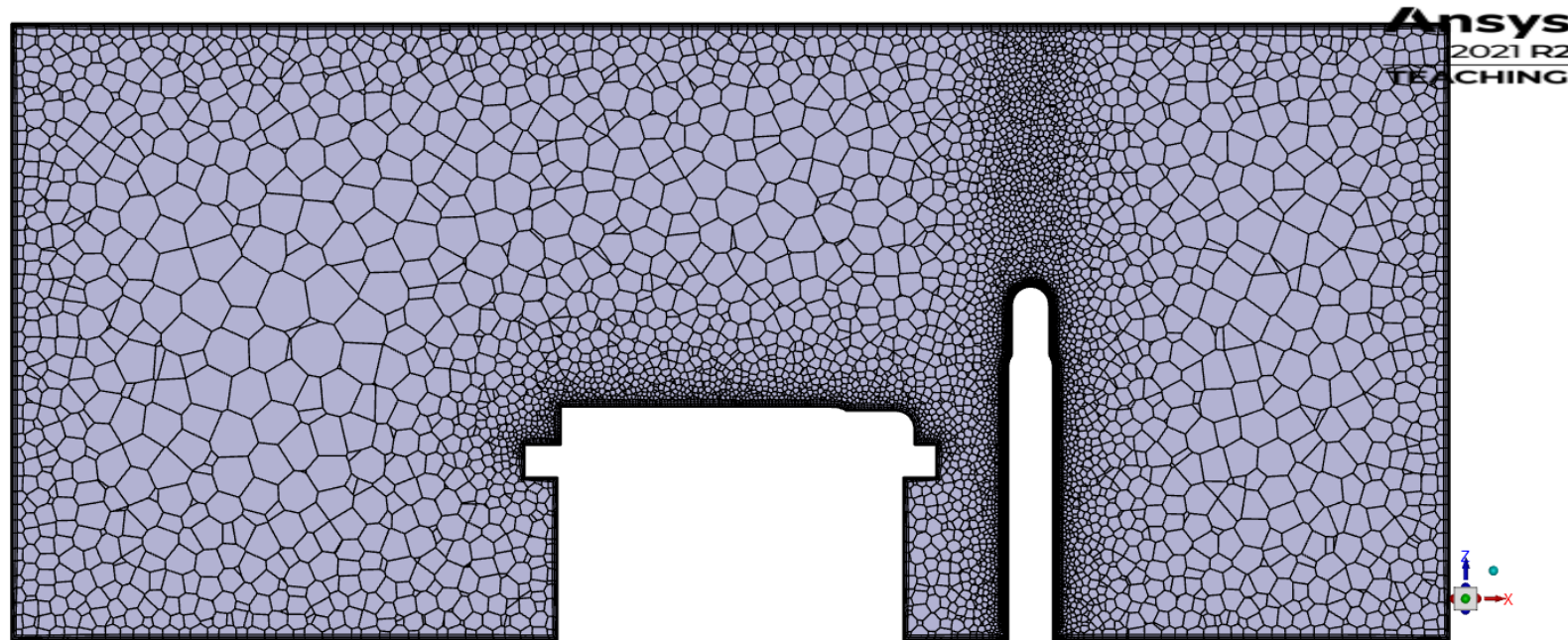
Spanwise distribution of the vertical velocity near the diffuser exit.

A quasi-uniform core region is observed, with variations within approximately 7% of the mean value and expected decay near the lateral boundaries due to wall effects.



Time-averaged vertical velocity field for a single heated manikin under zero-inflow conditions.

A buoyancy-driven plume forms above the heat source, characterised by a localised upward flow and ambient entrainment.



- 854,824 Cells

One-Thermal plume case

Solver and physics

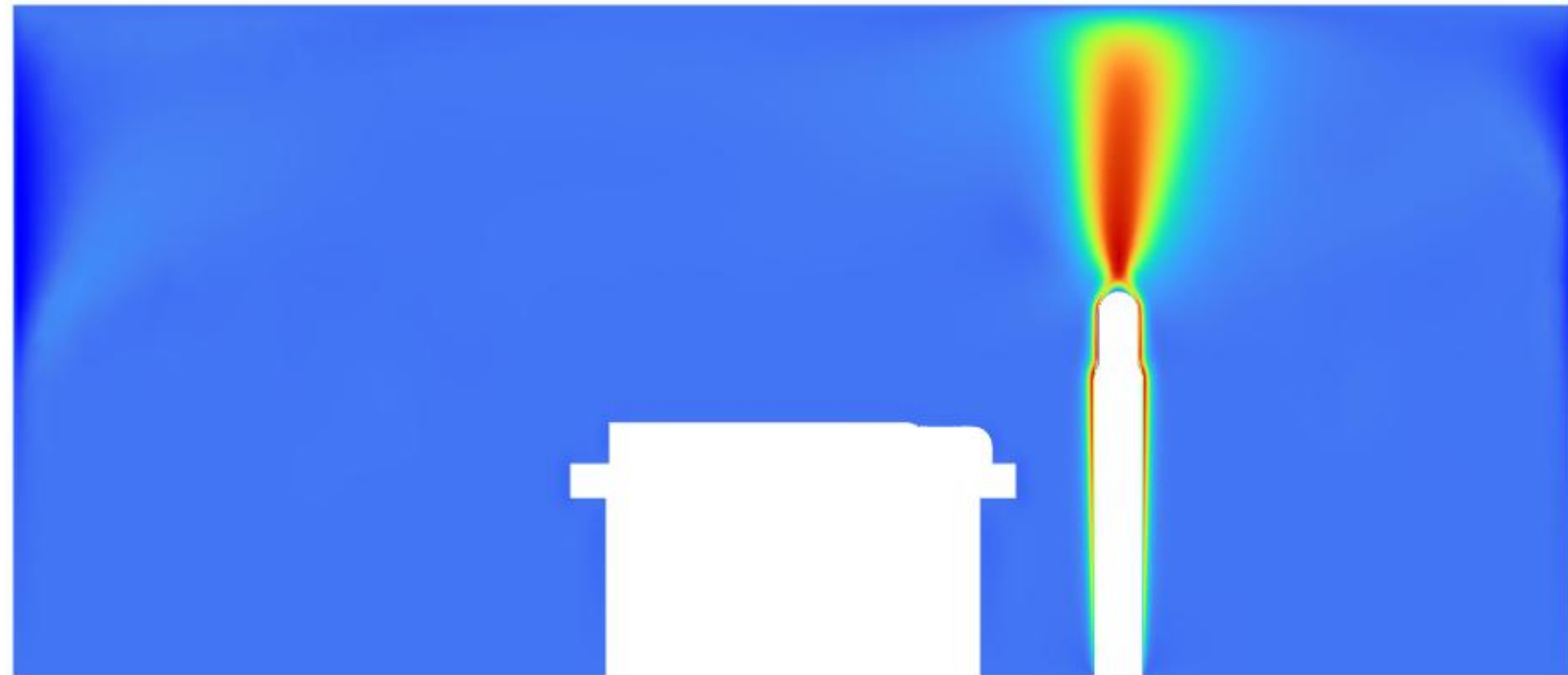
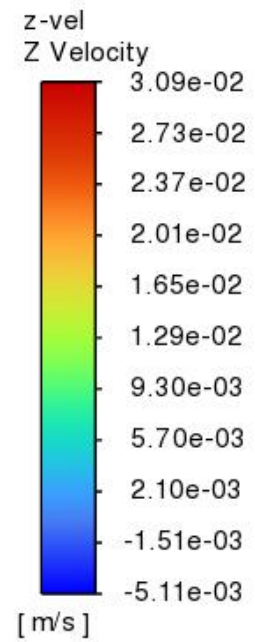
- Pressure-based, steady RANS simulation
- RNG $k - \epsilon$ turbulence model
- Enhanced Wall Treatment
- Energy equation enabled
- Gravity enabled, $g_z = -9.81 \text{ m/s}^2$
- Boussinesq approximation for water at 293.15 K

Boundary conditions

- Heated manikin: fixed effective wetted-surface temperature
- $T_{wall} = 323.15 \text{ K}$
- Other walls: fixed temperature
- $T = 293.15 \text{ K}$
- No imposed flow; buoyancy-driven plume only

Numerical scheme

- Coupled pressure–velocity coupling
- Pseudo-transient stabilization with automatic time scale
- Body Force Weighted pressure interpolation
- Least Squares Cell-Based gradients
- Final discretization: Second Order for momentum, energy, k , and ϵ



Isothermal case

Solver and physics

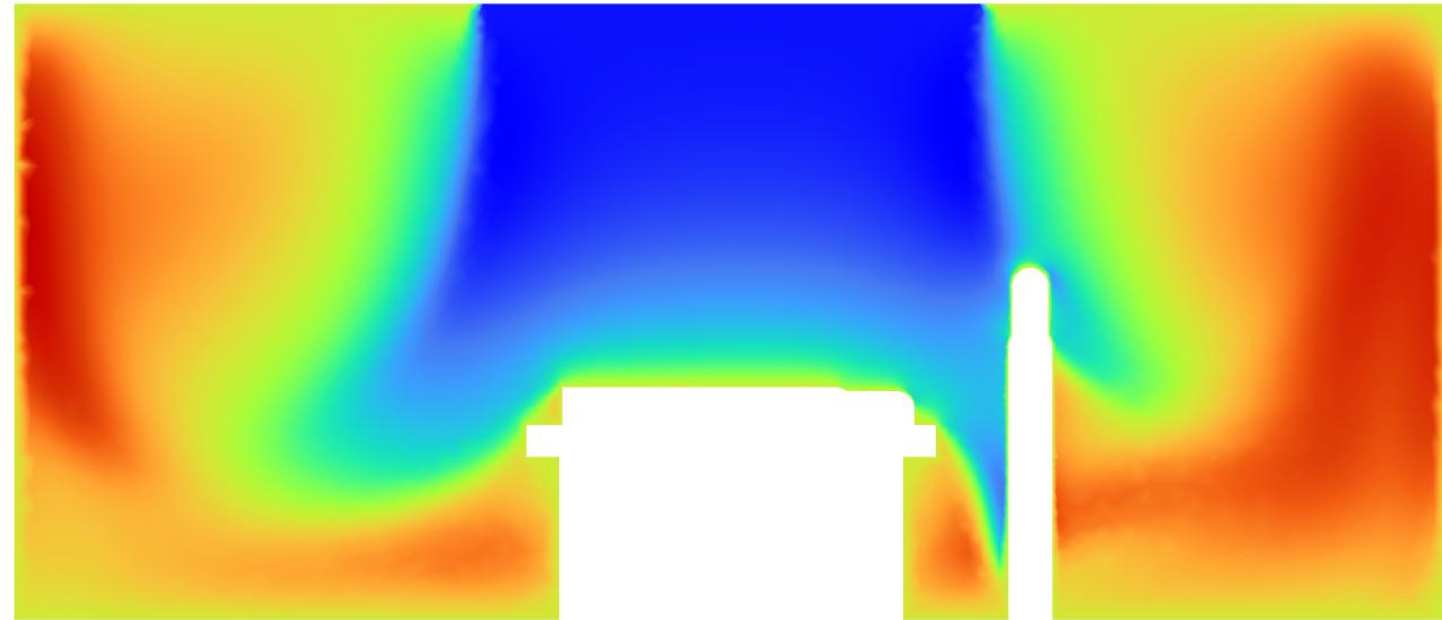
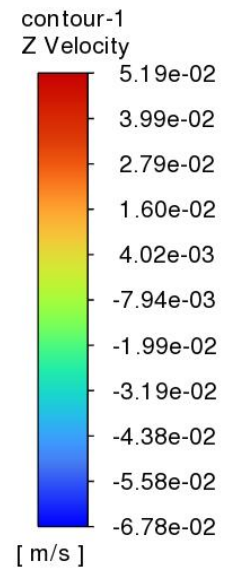
- Pressure-based, steady RANS simulation
- RNG $k - \epsilon$ turbulence model
- Enhanced Wall Treatment
- Energy equation OFF
- Gravity OFF
- Constant Density

Boundary conditions

- $v_{inlet} = 0.064 \text{ m/s}$
- Outlet: Pressure-outlet
- Other walls: No-slip, Adiabatic

Numerical scheme

- Coupled pressure–velocity coupling
- Steady-state
- Body Force Weighted pressure interpolation
- Least Squares Cell-Based gradients
- Final discretization: Second Order for momentum, energy, k , and ϵ



Conclusions:

- Designed the facility for reproducible and repeatable high-quality PIV measurements in a scaled operating-room model
- CFD simulations used as a support tool to validate the physical consistency of the PIV measurements

Future Steps:

- Complete the CFD/PIV comparison
- Build a larger PIV experimental database
- Develop reduced-order models for near “real-time” airflow reconstruction

■ Conference Papers and Presentations

- *Angiero T., Discetti S., Ianiro A.*, “PIV experiment in a scaled operating room with laminar airflow (LAF) ventilation”, the 10th International Congress of the Serbian Society of Mechanics Conference Proceeding, June 18-20, 2025, DOI: 10.46793/ICSSM25
- *Angiero T., Discetti S., Ianiro A.*, “A scaled model approach for analyzing airflow and ventilation in operating rooms using PIV”, RoomVent Conference 2026, September 15-18, 2026 | Prague, Czech Republic

■ Seminar

- HumanIC seminar - *Angiero, T.* “Scaled operating room experiments for airflow analysis, CFD validation, and reduced-order modelling”, via online, 21/09/2026

■ Research Stay

- 3-months long Research stay at the KTH (07/03/2026 – 06/07/2026)

1. Eloquest Marketing. (2018, July 11). *Financial impact of surgical site infections (SSIs)*. Eloquest Healthcare, Inc.
2. Jain, S., & Reed, M. (2019). Laminar air flow handling systems in the operating room. *Surgical Infections*, 20(2), 103–107. <https://doi.org/10.1089/sur.2018.258>
3. Sattari, A., & Sandberg, M. (2013). PIV study of ventilation quality in certain occupied regions of a two-dimensional room model with rapidly varying flow rates. *International Journal of Ventilation*, 12(2), 187–194. <https://doi.org/10.1080/14733315.2013.11684015>
4. Fallenius, B. E. G., Sattari, A., Fransson, J. H. M., & Sandberg, M. (2013). Experimental study on the effect of pulsating inflow to an enclosure for improved mixing. *International Journal of Heat and Fluid Flow*, 44, 108–119. <https://doi.org/10.1016/j.ijheatfluidflow.2013.05.004>
5. Zhang, J. S., Wu, G. J., & Christianson, L. L. (1993). A new similitude modeling technique for studies of nonisothermal room ventilation flows. *ASHRAE Transactions*, 99(Pt. 1).
6. Mesenhöller, E., Jacobs, S., Vennemann, P., & Hussong, J. (2022). Unsteady ventilation in a scaled room model with swirl ceiling diffusers. In *CLIMA 2022 conference proceedings*. <https://doi.org/10.34641/clima.2022.200>
7. Mukhaiber, H., & Turner, J. T. (2023, May). *On the circulation of air in an operating theatre: An experimental study* [Conference paper].
8. Stevenson, T. C., & Meter, S. M. (2013). *Comparison of CFD simulations of hospital operating room air distribution with experimental PIV results* [Conference paper]. ASHRAE.
9. de Santiago Casado, P. (2015). *Estudio de la ventilación en quirófanos y habitaciones de aislados infecciosos* [Doctoral dissertation, Universidad de Valladolid].



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Thank you! Questions?

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